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# MECHANICAL HARVESTING OF CLING PEACHES

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Mechanical harvesting of cling peaches is practical from both the engineering and the horticultural points of view, but successful mechanization requires careful management of well-designed equipment and orchards which have been horticulturally prepared for such harvesting. Losses resulting from failure to recover fruit, or from reduced quality, detract from the economic feasibility of machine harvesting, and over-all fruit loss of about 10 per cent would make machine harvest impractical at this time.

This publication discusses:

- design criteria, and operating procedures designed to obtain an economical mechanical harvesting system for cling peaches,
- the effect of mechanical harvesting on canning peach quality,
- how to modify trees so as to improve fruit recovery, reduce fruit injury, and minimize loss of yield due to such modifications.

For successful mechanical harvesting, cultural practices which induce uniform maturity should be employed. Irrigation practices which reduce soil compaction, and which do not delay harvesting, should be followed.

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# MECHANICAL HARVESTING OF CLING PEACHES[1]

## INTRODUCTION

Problems involved in the mechanical harvesting of cling peaches have been studied by the University of California for nearly two decades. In the first exploratory tests, fruit loss was excessive and harvesting equipment was too cumbersome and slow (Lamouria *et al.*, 1961); to be profitable, shakers should remove at least 95 per cent of the marketable fruit from trees. But because of an increasing scarcity of agricultural labor and an increased awareness that efficient machinery could be developed to help offset this loss, research continued and in this the University was joined by the U.S.D.A. One of the concepts vital to the program was the realization that successful approach to mechanical harvesting must take two basic problems into account—the engineering problem, and the horticultural problem.

**Engineering considerations.** Engineering must provide for machine design and operation to obtain (1) minimum injury to fruit during catching, collecting, conveying fruits, and filling bulk bins, (2) good maneuverability and movement of the harvester in the orchard, (3) a high percentage removal of fruits from trees, and (4) minimum damage to trees (Adrian *et al.*, 1969).

**Horticultural considerations.** These must provide for (1) removal of fruit at the best and most uniform stage of maturity, (2) tree modification to reduce injury to fruit as it falls through the tree and as it is removed, and (3) changes in cultural practices (Claypool *et al.*, 1969).

These engineering and horticultural factors must be considered when making economic evaluations, for the mechanical system (machines) working on the horticultural system (trees and fruit) must provide high-quality fruit at competitive prices. Under current conditions, about 16 per cent of the cash return on the crop goes to cover the cost of hand-harvesting. Therefore, the cost of machine harvest, including the value of fruit lost or damaged as a result of such harvesting, must not exceed the value of 16 per cent of the crop (Fridley and Adrian, 1968). Thus it is obvious that the most important engineering and horticultural considerations (over and above the initial costs of equipment) are those which lead to minimizing fruit loss, including the reduced value of damaged peaches.

## ENGINEERING: DESIGN AND OPERATION

Objectives of the engineering phase of the study were to eliminate the harvester as a source of fruit injury, to minimize field injury, to minimize field losses resulting from harvester design or operation, and to achieve enough harvesting speed for economic justification. Fruit injury on the harvester should be minimized by effective padding of hard surfaces, by development of deceleration systems to minimize damage from fruit-on-fruit impacts, by designing catching surfaces which produce minimum rebound of fruits and, finally, by design of a gentle fruit-handling system from catching surface to container. Field losses from fruits dropping to the ground should be reduced by providing sufficient catching

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area, and by designing a positive closure around the tree and the frame halves of the catching device. Losses caused by poor removal of fruit from the trees must be minimized by proper design and operation of the shaker. Achieving an economically feasible rate of harvest involves designing equipment having good maneuverability and minimum time-loss inherent in its operation.

## Drop tests

Drop tests were conducted in 1960 and 1961 to select materials with suitable characteristics and thickness for padding the hard surfaces of catching frames, and to evaluate stretched canvas as a catching surface (Fridley *et al.*, 1960, and Adrian *et al.*, 1961).

Table 1 shows results from a 10-foot drop onto different materials. Good cushioning resulted from a 1-inch thickness of expanded polyethylene, and excellent cushioning from a 3-inch thickness of polyurethane. Polyethylene seemed the most practical material because polyurethane requires excessive thickness and has poor durability. Padding of low density, such as sponge rubber or polyurethane, permitted fruits to impact onto the wood base unless thick pads were used. When one fruit was dropped on another severe bruising resulted to both. There was little bruising on stretched canvas which had no structural support in the catching area. The satisfactory results with stretched canvas led to the idea of minimizing fruit-on-fruit impact by using several strips of canvas webbing placed in two layers and held parallel in a staggered arrangement over the catching surface. Drop tests indicated good protection for falling fruit and the fruit under these strips.

Studies have shown that bruises are the result of shear failure in the fruit flesh (Fridley *et al.*, 1968). Therefore, bruises can be minimized by decreasing shear stresses caused by application of force. This can be done by reducing the magnitudes of force applied, or by distributing impact force over a greater surface area of the fruit. Padding tends to accomplish both effects because during impact the kinetic energy of the fruit is transferred to deformation of the pad and deformation of the fruit. If proper padding is used

TABLE 1

PER CENT OF FORTUNA AND PEAK DAMAGED BY A 10-FOOT DROP ONTO VARIOUS CATCHING SURFACES

| Catching surface | Degree of damage and per cent damaged* | | |
|---|---|---|---|
| | Undamaged or slightly bruised | Severely bruised | Split |
| | *Fortuna* | | |
| Control (no drop) | 99 | 1 | 0 |
| Sponge rubber 3/8-inch thick | 4 | 0 | 96 |
| Polyurethane 1-inch thick | 16 | 14 | 70 |
| Sponge rubber 3/4-inch thick | 45 | 2 | 53 |
| Polyurethane 2-inches thick | 76 | 12 | 12 |
| Stretched canvas | 92 | 8 | 0 |
| Fruit dropped on other fruit | 68 | 16 | 16 |
| Fruit hit by other fruit | 44 | 31 | 25 |
| | *Peak* | | |
| Control (no drop) | 98 | 2 | 0 |
| Polyurethane 1-inch thick | 38 | 41 | 21 |
| Polyurethane 1-3/4-inches thick | 84 | 14 | 2 |
| Expanded polyethylene 1-inch thick | 95 | 5 | 0 |
| Polyurethane 3-inches thick | 98 | 2 | 0 |

* Expressed as per cent of total fruit dropped.

TABLE 2

IMPACT ENERGY AND DROP HEIGHT NECESSARY TO BRUISE FRUITS OF VARYING FIRMNESS, AND PER CENT OF BRUISED FRUITS RESULTING FROM SIMULATED TRANSIT*

| Flesh firmness | Impact energy causing fruit bruising† | Maximum drop height for bruising peaches weighing ⅓ pound‡ | Fruit bruised during simulated transit on leaf-spring suspension§ |
|---|---|---|---|
| *pounds* | *inch-pounds* | *inches* | *per cent* |
| 2 | 0.3 | 0.9 | 96 |
| 4 | 1.1 | 3.3 | 79 |
| 6 | 3.2 | 9.6 | 45 |
| 8 | 4.2 | 12.6 | 27 |

* Maturity measured by flesh firmness as determined by using a 5/16-inch diameter tip.
† Impact energy and drop height are for impact on an unpadded surface.
‡ Average marketable peach weighs about ⅓ pound.
§ Data from O'Brien *et al.*, 1969.

it absorbs enough of the kinetic energy to reduce impact force to a tolerable level. At the same time, the fruit is imbedded in the padding and this increases the area of contact (Fridley *et al.*, 1964).

Bruising studies also demonstrated that as fruit matures it becomes increasingly susceptible to bruising. In other words, the maximum shear strength and therefore the maximum allowable impact energy decreases with maturation, as table 2 indicates. Table 2 also shows bruising resulting from simulated transit (O'Brien *et al.*, 1969). It has been said that fruits have a memory, and indeed if they are subjected to a number of impacts they have a lower tolerance than when hit only once (Fridley and Adrian, 1966). Table 3 shows the effect of hitting a fruit in one spot with several impacts of equal magnitude, and indicates that slight damage from minor impacts is additive.

TABLE 3

IMPACT ENERGY REQUIRED TO BRUISE CLING PEACH FRUITS BY HITTING THEM ONE OR MORE TIMES ON ONE SPOT*

| Number of impacts | Energy per impact |
|---|---|
| | *inch-pounds* |
| 1 | 0.33 |
| 2 | 0.24 |
| 5 | 0.16 |
| 10 | 0.11 |

* Firmness of fruit was 4 pounds, as measured by a pressure tester with a 5/16-inch tip. Impacts were applied to the cheek of each fruit with a 5/16-inch diameter die.

## Harvesting field trials

Harvesting investigations were conducted from 1959 through 1967, but at first they were exploratory in nature in order to understand the scope of the problem. In 1960, two commercial catching frames developed for harvesting prunes were modified by adding three layers of canvas decelerator strips over most of the catching area to minimize fruit-on-fruit impact. All exposed hard surfaces were covered with a ½-inch layer of sponge rubber. An inertia limb shaker and an impact limb shaker (Fridley *et al.*, 1960) were used in these tests. More extensive trials were conducted in 1963, using prune harvesting equipment modified by placing a 1-inch layer of expanded polyethylene over the entire catching surfaces (Claypool *et al.*, 1963). The unit on one side of the tree had a plywood base; the unit on the other had a 2 × 4-inch welded-wire base. Three offset layers of plastic webbing decelerators were mounted over the conveyors and over areas of the greatest concentration of fruit fall. A commercial inertia limb shaker was mounted on each unit. Grower orchards were used and trees were not modified for mechanical harvest.

These studies proved the need for having the harvester designed for peach trees, and for having the trees trained for machine use. Some tests conducted during these trials were not repeated, so their results are reported with other results in a later section (pages 12 and 20).

Fig. 1. Front view of harvester in shaking position. This machine was designed for research only on mechanical harvesting of cling peaches.

## Machine design

In 1966 and 1967, extensive field trials were made with an experimental harvester designed and constructed for use on cling peach trees which had been pruned for machine harvest (Adrian *et al.*, 1968); the design was primarily based upon knowledge gained in the exploratory trials. The harvester consisted of two self-

Fig. 2. Operator and shaker moving along track. Movement is actuated by two micro switches located by operator's feet.

propelled machines which worked side by side on opposite sides of the same tree. Each unit featured a main chassis upon which was mounted catching surfaces and a conveyor for moving fruit to the bin. It was decided that one limb shaker on each unit would give best removal for the various tree conditions which would be encountered. Tests conducted from 1960 through 1965 had shown that trunk shakers available at that time gave inconsistent removal and that results were frequently poor on trees having extensive hangers. To provide better visibility and easier positioning of shaker and frame, the operator was located within the catching area. The shaker and the operator's seat were mounted on a carriage which was hydraulically powered for fore and aft movement along a track. A limb shaker having an over-all length of 6 feet was used (this compares with about 12 to 15 feet for conventional limb shakers). The operator was protected from falling fruits by two deflectors, one of which extended along the track just above his knees as he faced the tree, with the other located over his head—the upper deflector also prevented fruit from falling on the sizing and bin-filling equipment located along the outside edge of the frame. The height of the upper deflector sometimes caused tree interference, but with trees pruned vase-shaped this was minimized.

Catching surfaces of the harvester were of fabric, and were designed to require minimum tension and thus reduce the amount of fruit bouncing. Fiberglass screen, vinyl-covered nylon, and hypalon-covered nylon were tested. The fiberglass screen resulted in the most bouncing of fruit, and the vinyl-covered nylon seemed to provide best dampening of fruit bounce. A deceleration system of neoprene tubing was used to minimize fruit-on-fruit impact on and near the conveyor (fig. 3)—this eliminated the fruit bouncing experienced with flat deceleration strips used in previous tests. Three layers of 2⅝-inch outside diameter by 1⅝-inch inside diameter tubes were used over the conveyor, and two layers of 3⅛-inch by 2⅛-inch tubes were used adjacent to the conveyor. Spacing between layers was 3 inches; center line spacing between tubes in the same layer was 7½ inches. Space between tubes was maintained by mountings at each end of the strips and on each side of the conveyor. With this arrangement, no adjustment or tightening of the decelerator tubes was required during the field testing.

The conveyor was 30-inches wide and was L-shaped and continuous in order to eliminate fruit injury caused by transfer of fruit from belt to belt. (It was necessary to use detachable link chain on the edges of the conveyor because of the L-shape.) The belt was 4-ply rubber, with rubber cleats bonded at 6-inch intervals; cleats were at an angle of 70° to the surface of the belt to help prevent fruit from rolling back on the inclined portion of the belt. The conveyor unit was mounted on the chassis perpendicular to the direction of

Fig. 3. Neoprene tubing used to decelerate fruit and minimize fruit-on-fruit impact on and near the conveyor.

travel and in line with the tree being harvested.

A parallel rod sizer was used for removing small fruit. This type of sizer has the disadvantage of sorting fruit on the basis of a minimum diameter, while Advisory Board grade is based on a maximum diameter perpendicular to the axis of a fruit. As a result some peaches which have flat areas tend to fall through the sizer, although they would pass Advisory Board grade. Sizers constructed on other principles no doubt would retain most fruit of marketable size, but the sizer used in the test had the advantage of a large capacity (which is essential on a mechanical harvester). Spacing between rods on the sizer was initially 2¼ inches, but was reduced to 2⅛ inches to minimize loss of fruit of marketable size.

Good bin-filler design is essential to minimize injury to the fruit going to the bin, so an arrangement of padded staggered baffles was designed as a bin-filler and to distribute fruit throughout the bin. The filler was simple, had no moving parts, and gave satisfactory results. In initial tests, bridging of fruit in contact within the filler sometimes formed a bridge that blocked a passage; however, this problem was solved by making minor modifications. A blower for removing leaves was also incorporated although it was found that the rod sizer removed most leaves, branches, trash, and small fruit. The catching surface was 27 feet long, and the combined width of the two halves was 25 feet. As there were elevated deflectors along the sides, the frame was big enough to catch nearly all fruits, including those receiving lateral momentum.

## Machine operation

Operation of the equipment required two operators and one man to take care of bins, but best results were achieved by having four men, with the fourth assisting with bins. This permitted better control in filling bins, and the two men not operating the equipment had some time to remove trash and culls from the bin.

Fig. 4. Front view of harvester in transport position. Empty bin is carried as shown.

At each tree the collection unit was side-shifted toward the tree to provide a closure along the tree row. As the conveyor side-shifted, it also lowered so that in the shaking position the conveyor rested on the ground; this located the seal around the trunk below the crotch of the tree. As the conveyor was side-shifted, a linkage simultaneously side-shifted and tilted the lower collection surfaces toward the conveyor. The edges of the catching frames nearest the tree row were flexible, so a good seal between frames and around the tree trunk was achieved and fruit loss was minimized; flexibility was provided by a loop of belting along the edge and by a nonrigid framework supporting the edge of the catching surface. With the frames in place around the tree, the operators moved along the track and shook each primary limb on their side of the tree. Care was taken to position the shaker as nearly perpendicular as possible to the limb being shaken; after each tree was shaken, the operators side-shifted the collection frame away from the tree again; the machine was then moved to the next tree.

Bins being filled were supported on an integral forklift and were lowered to the ground when full. As they were lowered, an empty bin supported on a set of rollers was automatically tilted so as to move onto the forklift. This empty bin was then raised to the filling position and after this a second empty bin (previously placed in the orchard) was manually put into position on the rollers.

## HORTICULTURAL: VARIETIES AND TREE MODIFICATION

Early studies showed that fruit damage resulting from mechanical harvesting differed in severity according to the structural characteristics of the trees (Claypool, *et al.*, 1965). Accordingly, more detailed research was done on this in 1966 and 1967, using orchards trained in the various systems common in California cling peach production. Peach varieties in four orchards were used in field tests. They were: Loadel and Peak in the Sacramento Valley, and Gaume and Halford in the Modesto area. All trees except Gaume were near full commercial size.

**Loadel.** Loadel trees planted in 1958 were trained to a modified Dahlgren system. These were mostly large, vigorous trees averaging five to six primary scaffold limbs; modification consisted of removing an occasional primary scaffold and about three secondary scaffold limbs per tree to eliminate one of two branches in the same vertical plane. Low brush was also removed, as were stubs in the lower half or two-thirds of the tree.

**Peak.** This variety, planted in 1955 and developed under the full Dahlgren system of pruning, had approximately 14 to 15 scaffolds per tree ranging from vertical to nearly horizontal. The first year's modification consisted of removal of many of these scaffolds in order to reduce the hazard of falling fruits hitting limbs, reduce the number of shaker attachments required, and facilitate movement of equipment. Because of the shape and structure of unmodified trees, it was impossible to get the catching frame through the orchard or have it close enough to the trees to permit harvest. Therefore, in this orchard there was no direct comparison between hand and machine-harvested fruits on unmodified trees.

**Gaume.** This young orchard, planted in 1962, and trained in the so-called University of California system, was included in the experiment to determine the feasibility of training young trees for mechanical harvesting. The trees were generally trained upright to the shape of a vase, with three or four primary branches from which a total of six or more secondary branches arose to form the bearing surface. There was some removal of primary and secondary branches, but the main modification was the removal of low brush which in young trees may account for a considerable portion of the bearing sur-

face. Unmodified trees were used in a comparison of machine harvesting with hand harvesting.

**Halford.** The Halford trees, planted in 1960, were trained in the University of California system also and were large for their age but were not yet in full production. Modification consisted of removal (but only occasionally) of a primary branch; however, one or two secondaries per tree were usually removed together with low brush. Also included in this group were trees from which only pruning stubs were removed, and control trees pruned in the same way as trees for hand harvesting.

As one of the primary objectives of this study was to determine the rate of yield recovery of modified trees, the same plots were used again in 1967. Only minor pruning adjustments were required to maintain the desired structure of modified trees. Peak presented the greatest problems because of severe modifications needed.

## HARVEST PROCEDURE

Harvest was scheduled for the 1st, 3rd, and 5th days of the normal harvest period. It was presumed that on the first day some fruit would be too green to pass industry maturity standards, that on the third day most fruit would be at the most desirable maturity, and that on the fifth day some fruit would be over-mature.

Data for each plot were collected on at least six representative trees selected before each day's operation. Machine harvest was compared with hand harvest from adjacent rows in the orchard to minimize variations in tree size and cultural factors. All fruit on the ground before harvest was collected and weighed. Fruit lost to the ground during harvest was collected, classified, and weighed, as was fruit left on the tree. Sample boxes of fruit were collected during harvest for detailed injury evaluation. Small fruit removed automatically by the size grader on the harvester was collected and size graded by ring to determine the number and weight of marketable fruit that the grader had discarded. Fruit in the sample boxes collected during harvest was evaluated for maturity immediately after harvest and for damage 24 hours later. Damaged fruits were classified into "minor," "moderate," and "severe" categories of bruises and cuts. Judging by previous studies, the category minor would not downgrade fruit for canning; the category moderate downgraded one-half of each peach; and severe downgraded the entire peach. The same method of sampling and evaluation was used for the 2 years these tests were conducted. Due to an accidental irrigation, the Gaume orchard was not harvested mechanically in 1967, but yield data were obtained.

## HARVEST RESULTS

The difference in amount of fruit recovery between machine and hand harvest results from differences in loss of yield associated with modification of trees, loss of fruit in the field, and loss of quality from fruit injury.

### Loss of yield

Table 4 compares marketable and total yield of peaches on unmodified and modified trees during 1966 and 1967 after modification in the winter of 1965–66. There was an obvious reduction in total yield as well as potentially marketable fruit in 1966 as a result of modification. The greatest reduction was found in the Peak and Loadel varieties which were trained, respectively, by the extreme

TABLE 4

TWO-YEAR YIELDS FROM UNMODIFIED TREES AND TREES MODIFIED FOR MACHINE HARVEST, SHOWING YIELD LOSS THE FIRST SEASON DUE TO MODIFICATION AND YIELD RECOVERY THE SECOND SEASON

| Variety | Year | Marketable yield | | | Total yield | | |
|---|---|---|---|---|---|---|---|
| | | Unmodified | Modified | Difference* | Unmodified | Modified | Difference* |
| | | *tons per acre* | | | | | |
| Loadel | 1966 | 16.6 | 14.6 | 2.0 | 20.7 | 18.1 | 2.6 |
| | 1967 | 17.6 | 19.0 | −1.4 | 22.7 | 23.3 | −0.6 |
| Peak | 1966 | 14.5 | 11.3 | 3.2 | 17.6 | 13.5 | 4.1 |
| | 1967 | 15.2 | 15.8 | −0.6 | 18.8 | 19.5 | −0.7 |
| Gaume | 1966 | 9.5 | 8.9 | 0.6 | 13.1 | 11.8 | 1.3 |
| | 1967 | 12.7 | 13.6 | −0.9 | 15.0 | 16.0 | −1.0 |
| Halford | 1966 | 13.3 | 12.9 | 0.4 | 17.2 | 15.9 | 1.3 |
| | 1967 | 12.5 | 12.6 | −0.1 | 13.9 | 14.3 | −0.4 |

* Yield of unmodified trees minus yield of modified trees = tons per acre.

Dahlgren system and by a modification between the Dahlgren and the University system. When vase-shaped trees which result from the University training system were modified, yield losses were not appreciable even in the crop year following modification. Loss of yield therefore bears a direct relationship to the amount of fruiting surface removed.

In 1967, yield from modified trees had equalled or exceeded yields from unmodified trees in every case. No attempt was made to determine whether the higher yields in 1967 from previously modified trees were significantly greater than those from unmodified trees, but indications are strong that peach trees are capable of rapid recovery of their yield capacity following even a severe modification. In fact, the rate of recovery far exceeded expectations.

## Field loss: fruit lost on ground and fruit left on tree

Table 5 gives data on field losses for 1963, and tables 6, 7, 8 give data on the 1966–67 tests. Field loss data for Gaume are not shown due to small tree size in 1966 and inability to machine harvest in 1967. The 1963 tests were on unmodified trees and the shaker could not be properly positioned on all limbs; as a result, much fruit was left in trees. Fruit removal was more satisfactory in 1966–67 because of improved shaker design; best results were attained on trees modified for machine harvest. In 1966, Loadel was not machine harvested, and in 1967 Gaume was not machine harvested—thus no 1966–67 information on recovery by machine is available for these.

Data on Loadel in 1967 (table 6) show that only slightly more marketable fruit was lost through the sizer, or from failure of the catching frame to collect, than was dropped to the ground by the hand picker. In this case the hand pickers left almost no marketable fruit on the tree, while the machine left a little over 3 per cent. The reason for this was that the hand pickers made a second harvest, and therefore direct comparisons of recovery are not appropriate. The cost of the second pick, although not calculated, is high in comparison to the amount of additional fruit recovered. Recovery by machine of 93 to 94 per cent of the marketable fruit is outstanding, and is not significantly different from that normally obtained by hand harvesters.

With Peak variety 4 per cent of the

TABLE 5

COMPARISON OF HAND AND MACHINE HARVEST IN FIELD RECOVERY OF LOADEL AND DIXON PEACHES, 1963*

| Harvest method | Fruit dropped during harvest | Fruit left on tree | Fruit delivered§ |
|---|---|---|---|
| | *Loadel* | | |
| Hand | 1 | 2 | 97 |
| Machine | 4 | 10 | 86 |
| | *Dixon* | | |
| Hand† | 2 | .. | 78 |
| Total hand | 4‡ | 2 | 94 |
| Machine | 3 | 9 | 88 |

* Expressed as per cent of total marketable fruit. Trees were unmodified.
† First pick of a 2-pick operation.
‡ Includes marketable fruit dropped between first and second harvest.
§ Potentially marketable fruit. Excludes preharvest drop, immature, small, and rots.

total fruit was not recovered by hand pickers (table 7), whereas 12 to 13 per cent was not recovered by machine. Several factors account for this large difference, the most important being that more marketable fruit fell through the sizer because the vertical axis of Peak is relatively short in comparison to its cheek or suture diameter. In 1967, when the sizer spacing was reduced to 2⅛ inches between rods, some fruit was lost to the ground that would have been marketable if measured in the conventional manner (broadest cheek or suture diameter). Another important factor was primarily that excessive scafford branches often made it impractical to shake all limbs even after the tree had been modified.

TABLE 6

LOSS OF MARKETABLE LOADEL PEACHES FROM MACHINE- AND HAND-HARVESTED TREES DUE TO FAILURE TO RECOVER, 1967

| Harvest date | Tree modification | Per cent of marketable crop not recovered | | Per cent of total marketable fruit delivered |
|---|---|---|---|---|
| | | Fruits dropped during harvest | Fruits left on tree | |
| | | *hand harvest** | | |
| 8/2 | None | 2.2 | 0.5 | 97 |
| 8/4 | None | 1.4 | 0.5 | 98 |
| 8/6 | None | 2.0 | 0.4 | 98 |
| | | *machine harvest* | | |
| 8/2 | Major | 4.2 | 2.8 | 93 |
| 8/4 | Major | 4.5 | 3.4 | 92 |
| 8/6 | Major | 2.0 | 4.0 | 94 |
| | | *machine harvest* | | |
| 8/2 | None | 1.3 | 2.7 | 96 |
| 8/4 | None | 2.7 | 5.3 | 92 |
| 8/6 | None | 2.8 | 4.2 | 93 |

* A second pick made on hand harvested fruit probably resulted in higher than normal recovery of marketable fruit.

TABLE 7

LOSS OF MARKETABLE PEAK PEACHES FROM MACHINE- AND HAND-HARVESTED TREES DUE TO FAILURE TO RECOVER, 1966–67

| Harvest date | Tree modification | Per cent of marketable crop not recovered‡ | | Per cent of total marketable fruit delivered§ |
|---|---|---|---|---|
| | | Fruits dropped during harvest | Fruits left in tree | |
| | | *hand harvest* | | |
| 8/1/66 | None | 1.0 | 1.0 | 98 |
| 8/3/66 | None | 1.5 | 1.5 | 97 |
| 8/5/66 | None | 2.5 | 2.5 | 95 |
| 8/18/67 | None | 1.0 | 1.0 | 98 |
| 8/20/67 | None | 3.0 | 2.0 | 95 |
| | | *machine harvest* | | |
| 8/1/66 | Major* | 6.4 | 4.6 | 89 |
| 8/3/66 | Major* | 6.1 | 4.9 | 89 |
| 8/5/66 | Major* | 4.8 | 7.2 | 88 |
| 8/18/67 | Major | 5.5 | 5.5 | 89 |
| 8/20/67 | Major | 7.8 | 5.2 | 87 |
| | | *machine harvest* | | |
| 8/5/66 | Slight† | 7.5 | 7.5 | 85 |
| 8/18/67 | Slight† | 6.5 | 5.5 | 88 |
| 8/20/67 | Slight | 6.5 | 7.5 | 86 |

* Low brush, water sprouts, stubs, and several primary and secondary scaffolds removed from each tree.
† A few low primaries and secondaries removed to permit operation of catching frame.
‡ Potentially marketable fruit.
§ Immature, small, and rotting fruits classed as culls.

The best recovery with machine harvest in 1966 was with Halford variety (table 8)—machine harvest here recovered between 92 and 93 per cent of the marketable fruits, or only about 3 per cent less than that recovered by hand harvesters. This is quite comparable to results on Loadel in 1967, and here again most loss of marketable fruit was due to the sizer. Only one harvest was made on Halford in 1967, and that was at the end of the harvest season when fruits were very ripe. Wet soil conditions had prevented earlier harvest, and by the time the soil dried a substantial percentage of the crop had dropped to the ground. Recovery of the marketable fruit by machine harvest, while somewhat less than that from hand harvesting, was still at a level considered to be in an acceptable economic range.

## Fruit injury

Table 9 shows mechanical damage to fruit at time of harvest, 1 day after harvest, and 2 days after harvest for fruit held under ambient conditions. Essentially no difference in damage between hand and machine harvested fruit was observed immediately after harvest, but differential damage became apparent by the following day and rotting of fruit damaged by mechanical harvest was severe by the second day. Small skin breaks not detectable immediately after harvest in mechanically harvested fruit become areas of high water loss and sites for infection. Fruits delayed in canning will probably vary greatly in degree of deterioration, depending on such factors as temperature, fruit injury, and disease inoculum present.

TABLE 8

LOSS OF MARKETABLE HALFORD PEACHES FROM MACHINE- AND HAND-HARVESTED TREES DUE TO FAILURE TO RECOVER, 1966–67

| Harvest date | Tree modification | Per cent of marketable crop not recovered† | | Per cent of total marketable fruit delivered‡ |
|---|---|---|---|---|
| | | Fruits dropped during harvest | Fruits left in tree | |
| | | *hand harvest* | | |
| 8/22/66 | None | 2.7 | 1.3 | 96 |
| 8/24/66 | None | 2.7 | 1.3 | 96 |
| 8/26/66 | None | 3.7 | 1.3 | 95 |
| 9/13/67 | None | 2.7 | 1.3 | 96 |
| | | *machine harvest* | | |
| 8/22/66 | Major* | 5.2 | 3.8 | 91 |
| 8/24/66 | Major* | 2.5 | 2.5 | 95 |
| 8/26/66 | Major* | ... | ... | .. |
| 9/13/67 | Major | 5.0 | 5.0 | 90 |
| | | *machine harvest* | | |
| 8/22/66 | None | 4.0 | 4.0 | 92 |
| 8/24/66 | None | 3.5 | 4.0 | 92 |
| 8/26/66 | None | 2.3 | 4.7 | 93 |
| 9/13/67 | None | 5.2 | 3.8 | 91 |

* Low brush, water sprouts, stubs, and several primary and secondary scaffolds removed from each tree.
† Potentially marketable fruit.
‡ Immature, small, and rotting fruits classed as culls.

TABLE 9

EFFECT OF HARVEST METHOD AND TIME BETWEEN HARVEST AND CANNING, ON CONDITION OF LOADEL PEACHES
(1963)

| Days between harvest and canning* | Harvest method | Classification of fruit marketable when harvested† | | | | | | | Rots | Estimated recovery of choice halves‡ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Undamaged fruits | Bruised | | | Cut | | | | |
| | | | Slight | Moderate | Severe | Slight | Moderate | Severe | | |
| | | *per cent of total fruit* | | | | | | | | |
| 0 | Hand | 47 | 24 | 14 | 4 | 9 | 2 | 0 | 0 | 88 |
| 0 | Machine | 47 | 10 | 3 | 0 | 28 | 7 | 5 | 0 | 90 |
| 1 | Hand | 49 | 12 | 14 | 3 | 14 | 7 | 1 | 0 | 85 |
| 1 | Machine | 37 | 6 | 9 | 5 | 22 | 13 | 8 | 0 | 76 |
| 2 | Hand | 31 | 21 | 15 | 3 | 24 | 3 | 0 | 2 | 86 |
| 2 | Machine | 6 | 19 | 8 | 2 | 23 | 11 | 2 | 28 | 57 |

* Fruit held in shade in orchard during 2-day holding period.
† Immature, small and rotting fruits eliminated at harvest; other fruits considered marketable.
‡ Choice halves in fresh fruit evaluation include all halves from fruits with no or slight damage and one-half of each fruit with moderate damage, 1 day after harvest.

TABLE 10

EFFECT OF HARVEST METHOD AND TREE MODIFICATION ON HARVEST DAMAGE TO LOADEL PEACHES

| Harvest date | Tree modification | Condition of marketable fruit 1 day after harvest* | | | | | | | Estimated per cent recovery choice halves† |
|---|---|---|---|---|---|---|---|---|---|
| | | Undamaged | Bruised fruit | | | Cut fruit | | | |
| | | | Slight | Moderate | Severe | Slight | Moderate | Severe | |
| | | *per cent of marketable fruit, hand harvest* | | | | | | | |
| 8/2/67 | None | 57 | 6 | 17 | 11 | 5 | 3 | 1 | 78 |
| 8/4/67 | None | 59 | 9 | 10 | 7 | 9 | 5 | 1 | 85 |
| 8/6/67 | None | 58 | 13 | 11 | 8 | 7 | 3 | 0 | 85 |
| | | *per cent of marketable fruit, machine harvest* | | | | | | | |
| 8/2/67 | Major | 46 | 4 | 8 | 7 | 11 | 17 | 7 | 73 |
| 8/4/67 | Major | 42 | 6 | 7 | 12 | 17 | 13 | 3 | 75 |
| 8/6/67 | Major | 41 | 5 | 6 | 6 | 16 | 22 | 4 | 76 |
| 8/2/67 | None | 42 | 3 | 7 | 5 | 12 | 21 | 10 | 71 |
| 8/4/67 | None | 40 | 10 | 7 | 3 | 22 | 14 | 4 | 82 |
| 8/6/67 | None | 38 | 8 | 7 | 2 | 22 | 17 | 6 | 80 |

* Immature, small, and rotting fruits eliminated at harvest, other fruits considered as marketable.

† Choice halves in fresh fruit evaluation include all halves from fruits with no or slight damage and half of each fruit with moderate damage, 1 day after harvest.

The percentage of choice halves recovered from potentially marketable fruit delivered to the grading station in 1966 and 1967 was highest in most cases from the hand-harvested lots (tables 10, 11, 12, and 13). Machine-harvested fruit evaluated 1 day after harvest averaged about 5 to 8 per cent less choice halves than did hand-harvested fruit. Differences in Peak were greater than this in 1966 (table 11). Recovery of estimated choice halves in hand-harvested lots averaged in the range of 78 to 83 per cent except for the Peak variety, where recovery was 90 per cent. This indicates that the crew in the Peak orchard was particularly careful, or that this variety is more resistant to damage. In the machine-harvested lots recovery of choice halves was between 71 and 90 per cent, with most lots being between 75 and 85 per cent. Low recovery of choice halves was generally associated with advanced maturity as was especially noted for Halford in 1967, when soil was too wet for machine operations during most of the harvest period.

Normally, hand harvesting produces more bruised than cut fruit, while cuts are the dominant injury in machine harvest. However, results in these tests varied considerably, depending on the quality of workmanship of hand pickers, on fruit maturity, on tree structure, and on over-all quality of the catching frame (including the catching surface, conveyor, and bin filling system).

## Summary of total recovery of fruit mechanically harvested

Table 14 summarizes differences in loss of machine-harvested fruit as compared with loss of hand-harvested fruit. On the average, about 5 per cent of marketable fruit was left in the tree or not caught by the catching frame, and another 5 per cent was lost because of mechanical injury. Such losses can be reduced by proper training of trees, use of good equipment to protect fruit during catching, conveying, and bin filling, and by harvesting when fruit reaches proper maturity. Gaume and Halford data for 1966 indicate that properly trained trees can be successfully harvested by a suitable machine with no more loss in fruit qual-

TABLE 11

## EFFECT OF HARVEST METHOD AND TREE MODIFICATION ON HARVEST DAMAGE TO PEAK PEACHES

| Harvest date | Tree modification | Condition of marketable fruit 1 day after harvest* | | | | | | | Estimated per cent recovery choice halves‖ |
|---|---|---|---|---|---|---|---|---|---|
| | | Undamaged | Bruised fruit | | | Cut fruit | | | |
| | | | Slight | Moderate | Severe | Slight | Moderate | Severe | |
| | | *per cent of marketable fruit, hand harvest* | | | | | | | |
| 8/1/66 | None | 75 | 9 | 3 | 1 | 10 | 2 | 0 | 96 |
| 8/3/66 | None | 58 | 11 | 12 | 5 | 10 | 4 | 0 | 87 |
| 8/5/66 | None | 63 | 8 | 10 | 5 | 10 | 4 | 0 | 88 |
| 8/18/67 | None | 82 | 2 | 5 | 4 | 3 | 4 | 0 | 91 |
| 8/20/67 | None | 78 | 3 | 13 | 3 | 1 | 2 | 0 | 89 |
| | | *per cent of marketable fruit, machine harvest* | | | | | | | |
| 8/1/66 | Major | 49 | 7 | 6 | 2 | 18 | 14 | 4 | 84 |
| 8/3/66 | Major | 51 | 8 | 8 | 2 | 16 | 11 | 4 | 84 |
| 8/5/66 | Major | 32 | 8 | 17 | 8 | 14 | 15 | 6 | 70 |
| 8/18/67† | Major | 77 | 4 | 3 | 2 | 4 | 7 | 3 | 90 |
| 8/18/67‡ | Major | 66 | 3 | 3 | 6 | 6 | 12 | 4 | 83 |
| 8/20/67 | Major | 64 | 4 | 12 | 4 | 3 | 11 | 2 | 83 |
| 8/5/66 | Slight | 39 | 7 | 14 | 10 | 11 | 15 | 4 | 71 |
| 8/18/67† | Slight§ | 67 | 3 | 3 | 2 | 6 | 16 | 3 | 85 |
| 8/18/67‡ | Slight | 61 | 5 | 6 | 5 | 7 | 11 | 5 | 82 |
| 8/20/67 | Slight | 56 | 4 | 13 | 4 | 7 | 10 | 6 | 78 |

* Immature, small and rotting fruit eliminated at harvest, other fruits considered as marketable.
† Most fruit near minimal maturity.
‡ Most fruit near optimal maturity.
§ A few primary and secondary branches removed in winter 1965–66 to permit operation of harvester.
‖ Choice halves in fresh fruit evaluation include all halves from fruits with no or slight damage and half of each fruit with moderate damage, 1 day after harvest.

TABLE 12

## EFFECT OF HARVEST METHOD ON DAMAGE TO GAUME PEACHES

| Harvest date | Condition of marketable fruit 1 day after harvest* | | | | | | | Estimated per cent recovery choice halves† |
|---|---|---|---|---|---|---|---|---|
| | Undamaged | Bruised fruit | | | Cut fruit | | | |
| | | Slight | Moderate | Severe | Slight | Moderate | Severe | |
| | *per cent of marketable fruit, hand harvest* | | | | | | | |
| 8/16/66 | 63 | 11 | 9 | 4 | 8 | 4 | 1 | 89 |
| 8/18/66 | 51 | 10 | 14 | 12 | 7 | 5 | 1 | 76 |
| 8/21/66 | 44 | 6 | 14 | 20 | 9 | 5 | 2 | 69 |
| | *per cent of marketable fruit, machine harvest* | | | | | | | |
| 8/16/66 | 57 | 11 | 9 | 3 | 10 | 7 | 3 | 86 |
| 8/18/66 | 53 | 13 | 9 | 9 | 8 | 6 | 2 | 81 |
| 8/21/66 | 45 | 6 | 14 | 20 | 3 | 9 | 3 | 66 |

* Immature, small, and rotting fruit eliminated at harvest, other fruits considered as marketable.
† Choice halves in fresh fruit evaluation include all halves from fruits with no or slight damage and half of each fruit with moderate damage, 1 day after harvest.

TABLE 13

## EFFECT OF HARVEST METHOD AND TREE MODIFICATION ON HARVEST DAMAGE TO HALFORD PEACHES

| Harvest date | Tree modification | Condition of marketable fruit 1 day after harvest* | | | | | | | Estimated per cent recovery choice halves† |
|---|---|---|---|---|---|---|---|---|---|
| | | Undamaged | Bruised fruit | | | Cut fruit | | | |
| | | | Slight | Moderate | Severe | Slight | Moderate | Severe | |
| | | *per cent of marketable fruit, hand harvest* | | | | | | | |
| 8/22/66 | None | 60 | 9 | 9 | 5 | 9 | 7 | 1 | 86 |
| 8/24/66 | None | 59 | 9 | 9 | 13 | 7 | 3 | 0 | 81 |
| 8/26/66 | None | 64 | 8 | 8 | 12 | 5 | 3 | 0 | 82 |
| 9/13/67 | None | 63 | 8 | 10 | 9 | 4 | 6 | 0 | 83 |
| | | *per cent of marketable fruit, machine harvest* | | | | | | | |
| 8/22/66 | Major | 62 | 9 | 6 | 3 | 11 | 8 | 1 | 89 |
| 8/24/66 | Major | 53 | 10 | 14 | 8 | 7 | 7 | 1 | 80 |
| 8/26/66 | Major | 68 | 6 | 4 | 6 | 5 | 8 | 3 | 85 |
| 9/13/67 | Major | 52 | 8 | 10 | 11 | 8 | 9 | 2 | 77 |
| 8/24/66 | None | 59 | 9 | 8 | 8 | 8 | 7 | 1 | 83 |
| 8/26/66 | None | 63 | 6 | 9 | 7 | 7 | 6 | 2 | 83 |
| 9/13/67 | None | 47 | 11 | 9 | 6 | 7 | 10 | 10 | 75 |
| 8/22/66 | Minor | 60 | 8 | 7 | 4 | 9 | 11 | 1 | 86 |
| 8/24/66 | Minor | 66 | 7 | 6 | 3 | 8 | 8 | 2 | 88 |

* Immature, small, and rotting fruit eliminated at harvest, other fruits considered as marketable.
† Choice halves in fresh fruit evaluation include all halves from fruits with no or slight damage and half of each fruit with moderate damage, 1 day after harvest.

TABLE 14

## INCREASED LOSS (all tests) OF MACHINE-HARVESTED FRUIT OVER HAND-HARVESTED FRUIT DUE TO MECHANICAL DAMAGE AND DIFFERENCES IN RECOVERY*

| Variety | Loss due to fruit left in tree | Loss due to fruit harvested but not collected | Loss due to mechanical damage |
|---|---|---|---|
| | *per cent of total marketable fruit, 1966* | | |
| Peak | 3 | 4 | 10 |
| Gaume | .. | 2 | 2 |
| Halford | 2 | 1 | −2† |
| | *per cent of total marketable fruit, 1967* | | |
| Loadel | 3 | 1 | 7 |
| Peak | 4 | 3 | 7 |
| Halford | 2 | 2 | 7 |

* Figures in this table arrived at by subtracting fruit losses in hand harvest from fruit losses in machine harvest.
† Less fruit damaged by machine harvest than by hand harvest.

TABLE 15

INCREASED LOSS OF MACHINE-HARVESTED NUMBER 1 GRADE FRUIT OVER HAND-HARVESTED FRUIT DUE TO MECHANICAL DAMAGE AND DIFFERENCES IN RECOVERY

(Cling Peach Advisory Board Study, 1966 and 1967)*

| Variety | Loss due to fruit left in tree | Loss due to fruit harvested but not collected | Loss due to mechanical damage |
|---|---|---|---|
| | *per cent of total number one grade fruit, 1966* | | |
| Fortuna | 6 | 4 | .. |
| Paloro | .. | .. | 25 |
| Halford (6 yr. old) | 6 | 4 | .. |
| Halford (23 yr. old) | 6 | 13 | 10 |
| Peak | 6 | 1 | 21 |
| | *per cent of total number one grade fruit, 1967* | | |
| Fortuna | .. | .. | 22 |
| Andora | .. | .. | 15 |
| Carolyn | .. | .. | 10 |
| Paloro | .. | .. | 13 |
| Peak | .. | .. | 4 |

* Figures in this table arrived at by subtracting fruit losses in hand harvest from fruit losses in machine harvest.

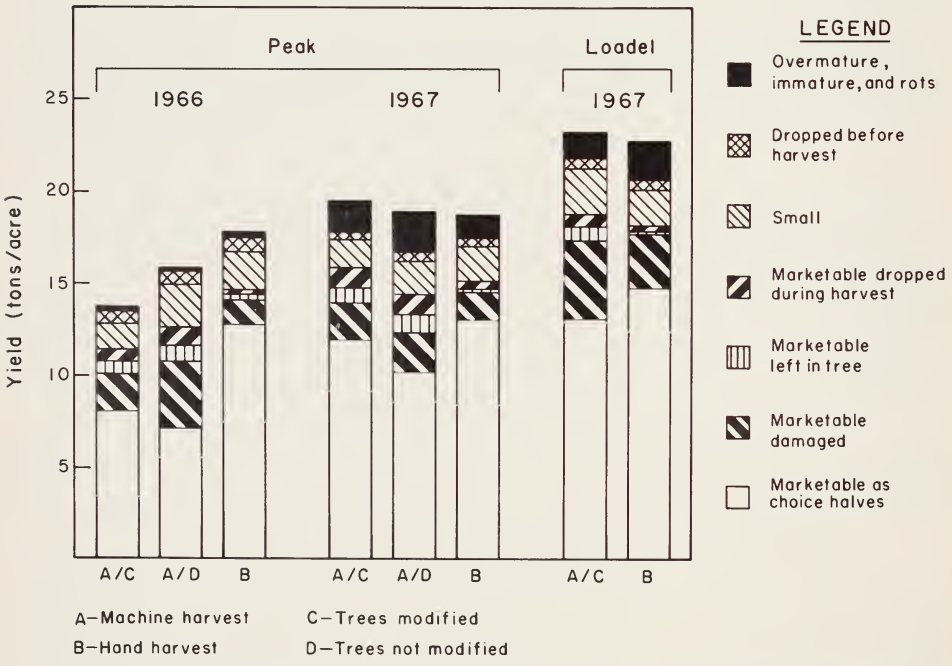


Fig. 5. Summary of harvest results on Peak and Loadel peaches with yields categorized into field losses and fruit quality.

ity than results from some hand-picking operations.

Figures 5 and 6 summarize the 1966 and 1967 harvest results. Similar data (table 15) were obtained by the Cling Peach Advisory Board during 1966 and 1967 from studies of a number of growers' orchards using a variety of commercial equipment. The procedure used in grading the fruits was the same as that previously described. Somewhat greater losses—particularly losses due to mechanical injury—were encountered in these tests than in those summarized in table 14. Improvements in tree structure, in harvester design, and in operation of equipment are necessary to reduce these losses.

## Effect of mechanical harvest on canning quality

In evaluating mechanical damage to fruits during harvest it is important that the information be applicable to canning grades. Therefore, fruits from a number of lots harvested in 1960 were graded as fresh whole fruit, on the cannery line, and again after processing. Table 16 shows the relationship between choice halves after processing and estimates of choice halves based upon classification of whole fresh fruit. The results indicate that fresh fruit evaluation can be used to accurately predict yield of choice grade canned fruit.

In addition to field evaluation, extensive canning line studies of peeled peaches were made in 1966 (table 17) using fruit from hand and machine harvested bins delivered to the cannery on commercial line-haul trucks. Placement of bins on trucks and trailers followed a predetermined pattern designed to give comparable positioning to hand and machine harvested fruit, thus eliminating bin position as a factor in the final results. All lots from 1966 University harvest trials were included in the study. Bins of peaches for the 29 treatment lots ranged from 2 to 13, each averaging between 7 and 8. Periodic random samples for quality evaluation were taken as the bins for

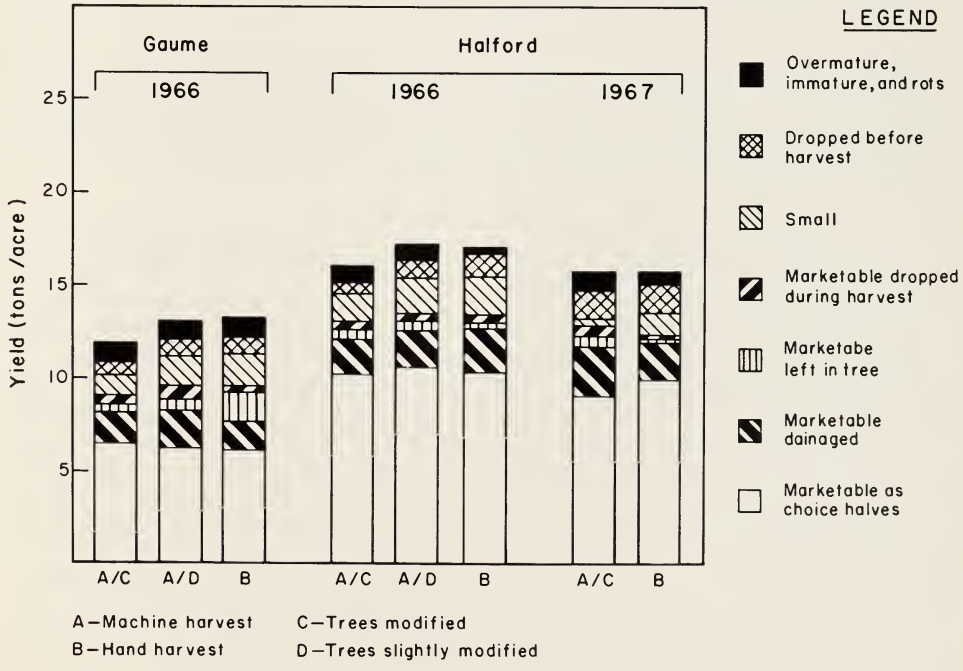


Fig. 6. Summary of harvest results on Gaume and Halford peaches with yields categorized into field losses and fruit quality.

TABLE 16

PER CENT OF CHOICE HALVES FROM FRESH FRUIT EVALUATION COMPARED TO PER CENT OF CHOICE HALVES FROM PEELED AND PITTED FRUIT ON CANNING LINE, 1960

| Harvest date | Harvest method* | Per cent of choice halves from two evaluations | |
|---|---|---|---|
| | | Fresh-fruit evaluation† | Canning-line-processed fruit evaluation‡ |
| | | *Gaume* | |
| 8/18 | Hand | 95 | 95 |
| | Frame B | 90 | 86 |
| 8/21 | Hand | 98 | 95 |
| | Frame B | 90 | 90 |
| | | *Halford* | |
| 8/29 | Hand | 98 | 94 |
| | Frame A | 87 | 86 |
| 9/2 | Hand | 94 | 94 |
| | Frame A | 80 | 80 |
| 9/7 | Hand | 97 | 93 |
| | Frame A | 91 | 84 |
| Average, both varieties | Hand | 96 | 94 |
| | Frame | 88 | 85 |

* The catching frames A and B were commercial units of different manufacturers both fitted with decelerator strips over conveyors.

† Choice halves in fresh fruit evaluation include all halves from fruits with no or slight damage, slightly cut fruits, and half of each fruit with damage.

‡ Choice halves of peeled and pitted fruit on canning line include all halves that are not obviously discolored (brown) as a result of mechanical damage.

NOTE: Fresh and canning line evaluations involve the same fruit.

each lot were run through the canning line and resulted in a large number of daily samples representative of the lots. Classification was limited to an evaluation of mechanical damage (cuts and bruises) and their effect on amount of recovery of choice halves. Several significant points are illustrated by these data: (a) there is excellent agreement in fruit-quality evaluation between fresh fruit in the field and peeled fruit on the canning line, with each evaluation taken approximately 1 day after harvest; (b) fruit quality generally is lowered as harvest is delayed and peaches become more mature; (c) cannery grade is likely to be a little lower than field grade, perhaps due to added injury during transit; and (d) the grade of peaches collected by a well-protected frame is close to that of hand harvest.

Previous studies have indicated that many bruises and cuts occurring during harvest can be evaluated almost immediately. Thus, it may be possible to evaluate mechanical damage soon after harvest to obtain a reasonable indication of quality at the cannery should this be desired.

## Importance of fruit maturity in mechanical harvesting

Fruit maturity is highly important in mechanical harvesting, both from the standpoint of maturity as a quality factor and maturity as it affects bruising. Fruits having a greenish hue will not meet color requirements, and those of advanced maturity may fail to process as choice grade fruits. Furthermore, fruits advanced in maturity tend to bruise very easily.

## Selective removal of mature fruits from trees having varied fruit maturity

Cling peaches on any one tree vary in maturity as measured by industry stand-

TABLE 17

ESTIMATE OF CHOICE HALVES FROM FRESH FRUIT AT ORCHARD AND ON CANNING LINE 1 DAY AFTER HARVEST, 1966

| Harvest method | Tree modification* | Per cent recovery choice halves | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Orchard evaluation† | | | | Canning line evaluation | | | |
| | | Pick 1 | Pick 2 | Pick 3 | Ave. | Pick 1 | Pick 2 | Pick 3 | Ave. |
| | | *Peak* | | | | | | | |
| Hand | None | 96 | 87 | 88 | 90 | 87 | 79 | 75 | 80 |
| Machine | Minor | .. | .. | 72 | .. | .. | .. | 65 | .. |
| Machine | Major | 84 | 86 | 70 | 80 | 86 | 76 | 63 | 75 |
| | | *Gaume* | | | | | | | |
| Hand | None | 89 | 76 | 69 | 78 | 86 | 86 | 82 | 85 |
| Machine | None | 86 | 82 | 61 | 76 | 88 | 87 | 81 | 85 |
| Machine | Major | 85 | 80 | 71 | 79 | 86 | 80 | 80 | 82 |
| | | *Halford* | | | | | | | |
| Hand | None | 86 | 81 | 83 | 83 | 81 | 79 | 81 | 80 |
| Machine | None | .. | 84 | 84 | 84 | .. | 78 | 79 | 78 |
| Machine | Minor | 86 | 88 | .. | 87 | 86 | 84 | .. | 85 |
| Machine | Major | 89 | 81 | 85 | 85 | 82 | 77 | .. | 80 |
| | | *average all varieties* | | | | | | | |
| Hand | None | .. | .. | .. | 84 | .. | .. | .. | 82 |
| Machine | All types | .. | .. | .. | 80 | .. | .. | .. | 79 |

* Tree modifications as described on pages 9 and 10.

† Choice halves in fresh fruit evaluation include all halves from fruits having no or slight damage and one-half of each fruit with moderate damage.

NOTE: Some variability shown is probably due to sample variability, inasmuch as the same fruits were not evaluated in both ways in 1966, whereas in 1960 identical fruits were evaluated fresh, then pitted, peeled, canned and re-evaluated (table 16).

ards of flesh color and flesh firmness. Cultural and varietal factors and location of the fruit on the tree all influence the degree of variability. In the past, several hand pickings have been made to obtain maximum recovery of mature fruits. More recently, increasing labor costs and declining labor availability have forced growers to make no more than two pickings and more often only a single picking. Initially, it was thought that shaking trees or limbs might be done selectively to remove only riper peaches, as these can be detached with less force than greener ones. This would permit two harvests and consequently a greater potential recovery of marketable fruit. Accordingly, tests using an inertia limb shaker, an inertia trunk shaker, and an impact knocker (Fridley and Adrian, 1966) were conducted on typical trees of four varieties of cling peaches. The degree of selectivity was determined by giving the trees a light shake, collecting the fruit, then shaking vigorously to remove all the fruit that could be removed thusly, and then handpicking the remaining fruit. Fruit removed at each step was classified separately as to maturity. Data shown in table 18 indicate no differences in maturity between peaches harvested by selective shaking and those left on the tree. The data are for Halford variety but are typical of other varieties tested.

TABLE 18

PER CENT OF TOTAL HALFORD FRUIT REMOVED BY SELECTIVE SHAKING AND PER CENT OF MATURE FRUIT IN FRUIT REMOVED COMPARED TO PER CENT TOTAL MATURE FRUIT PER TREE

(Records from 6 Trees)

| Type of shaker | Per cent of total fruit removed by selective shake | Per cent of mature fruit in fruit removed selectively | Per cent of mature fruit in total fruit on tree |
|---|---|---|---|
| Limb (tree 1)* | 84 | 83 | 84 |
| Limb (tree 2) | 78 | 65 | 65 |
| Impact (tree 3) | 66 | 62 | 61 |
| Impact (tree 4) | 72 | 64 | 61 |
| Trunk (tree 5)† | 61 | 92 | 88 |
| Trunk (tree 6) | 70 | 52 | 51 |

* Limb shaker operated at 400–500 cycles per minute. Stroke approximately 1 ½ inches.
† Trunk shaker operated at 750 cycles per minute. Stroke approximately ½ inch.

Limb structure, position of fruit on limbs, and location of limbs in tree had a more pronounced effect on the ease of removal than did fruit maturity. Because most immature fruit is in the lower more rigid region of the tree, the better vibration transmission in this region offsets any maturity difference. Wire braces frequently used to support limbs tend to dampen vibration transmission; this may be less of a factor when the whole tree is shaken simultaneously than when a limb shaker is used.

If selective removal of fruit had been possible an additional problem would have been encountered. About 20 per cent of the fruits remaining on the tree after shaking had skin breaks where the shoulder of the fruit was in contact with the twig. Observations indicate that 2 or 3 days after injury a high percentage of such fruit may decay, with the per cent depending upon inoculum present. Considering the poor degree of selectivity, the probability of loss due to decay of injured fruit left on the tree, and the fewer acres which can be harvested if trees have to be shaken twice, it seems impractical to attempt selective shaking of fruits within individual trees.

Tests on apricots have indicated that where there is considerable variability in maturity from tree to tree, a system of selective harvesting is practical if each tree is harvested when a high percentage of fruit is in the desirable maturity range. If the harvester can be moved quickly down the row, trees having mostly mature fruit can be marked for harvest ahead of the harvester, thus eliminating loss of time by the harvest crew. Depending on the acreage to be covered and the variability of maturity, two or more passes through peach orchards may give optimum profit. With greater industry concern now expressed in relation to advanced maturity as a grade defect, it appears likely that two passes through the orchard will not only be often justified but may even be an essential management practice.

Flesh firmness as well as flesh color should be used as harvest guides. Obviously, most fruit should pass the minimum color standard for the industry, but at the same time harvest of each variety should be completed before many fruits reach an advanced stage of maturity, as indicated by attaining a flesh firmness of 3 to 4 pounds using a 5/16-inch tip on the firmness tester. It appears likely that new grade rules relating to advanced maturity will result in changes in harvest management, and this should greatly reduce the amount of overripe fruit delivered to the grading station.

# ECONOMIC PROJECTIONS

The key to economic feasibility of mechanical harvesting is the number of tons of cling peaches harvested per season by one machine. This is directly related to the time required to harvest an acre and the yield per acre. Unlike hand harvest where costs are usually on a per ton basis, machine harvesting costs are essentially on a tree basis since the basic unit is the tree and not the yield. Thus, the cost per ton will diminish with machine harvest as the yield per tree (and thus per acre) increases.

To indicate the economic feasibility associated with mechanical harvesting of cling peaches, calculations have been made to cover a number of different situations. The hand harvest costs used were $15.00 per marketable ton of fruit at the grading station; this includes container distribution and collection, picker costs, picker supervision, and depreciation and interest on picking equipment. The cost estimate may be low for some areas and high for others, but it serves as a base for comparing hand and machine harvest costs.

In calculating machine-harvest costs (fig. 7), the machine was valued at $25,000. It was depreciated in 5 years and interest charged at 8 per cent. The annual fixed cost including depreciation, interest, and taxes was calculated to be $6,126; operating costs were estimated to be $100 per day for four men, fuel, and repairs, or $42 per acre based upon a harvest rate of 30 trees an hour and an 8-hour day. The rate of harvest and personnel requirements were assumed to be the same regardless of yield per acre.

Figure 7 compares the cost per ton for machine harvest to hand harvest costs at specific yield levels, fruit losses, and harvest rates. The top graph in figure 7 shows the importance of yield, the middle graph the importance of fruit loss, and the bottom graph the importance of harvest rate. The losses associated with machine harvest include loss of fruit in the field and lowering of quality. An on-tree value of $63 per ton is assumed ($78 per ton price—$15 per ton harvest cost). A total fruit loss and quality reduction of 10 per cent more than hand harvesting could not be justified by machine harvest in low-yielding small orchards. A break-even point for a fruit loss of 10 per cent would be reached with a 16-ton yield if about 90 acres were harvested at a rate of 30 trees per hour. This might require operation of the machine for more than one shift during part of the season. With a high yield, the chances for success are better. Harvest rate is not particularly important in terms of harvest cost as long as each variety is harvested while the fruit is of satisfactory maturity.

It is common practice for cling peach growers to have a succession of varieties that begin in July and continue into September so that a picking crew can be kept busy for the full harvest season, which may last 40 to 50 days depending on the variety sequence. Since canneries accept fruit 6 days a week, the harvest period can be about 34 to 43 working days.

The economic advantages of keeping a mechanical harvester busy are obvious. Equally obvious is the problem of the small operator—50 acres or less—who may need to consider cooperative ownership of a harvester or custom harvesting. (The estimate of 50 acres as the minimum size orchard to justify expenditure for a mechanical peach harvester would apply only under current labor and economic conditions. This figure may change in the future.) With present costs of labor and equipment, hand harvesting is less expensive than machine, but competition for labor and the reluctance of many to work at agricultural manual labor may increase hand harvest costs and thus increase the use of machines. At the present time it appears that a break-even point has been reached or surpassed for large operators.

The potential for increasing economic feasibility by night harvesting was explored during the 1963 tests. Cool temperatures were advantageous for opera-

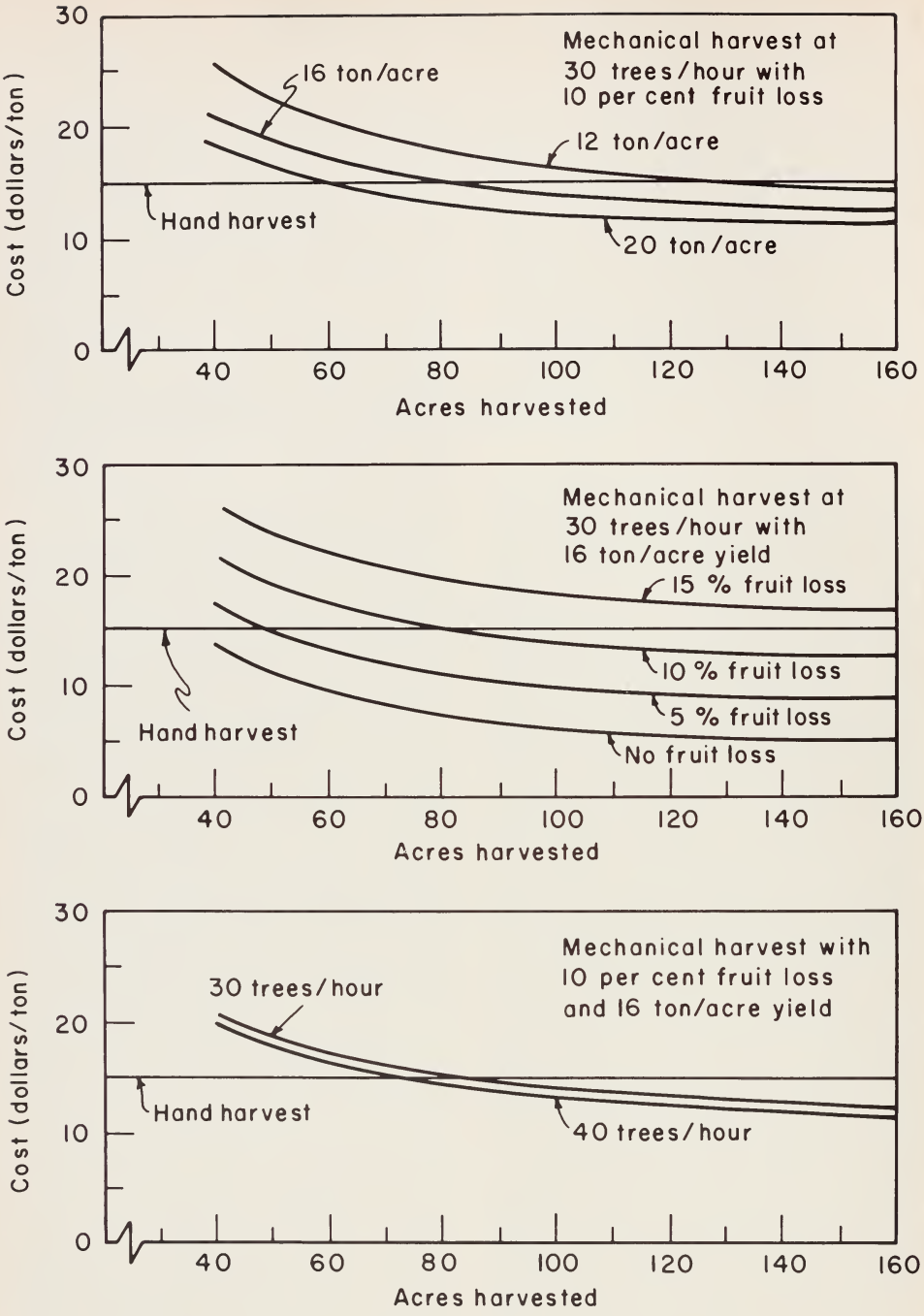


Fig. 7. Estimated cost of harvesting cling peaches by hand and by machine as related to acreage harvested, harvest rate yield, and loss in yield or grade of fruit. Value of fruit on tree estimated at $63 per ton ($78 per ton price—$15 per ton harvest cost).

tors, who were less troubled by dust and peach fuzz than during daytime operations. Field losses were not altered by night operation, and rate of harvest was not reduced. Whitewashing the trunk and lower portion of primary limbs made equipment operation quite easy; in fact, darkness was a greater handicap to handling bins than to the actual harvest operation. Subsequent tests of night harvest by several growers generally confirm the above findings. The Cling Peach Advisory Board reports "Any unfavorable conditions tend to be magnified at night. For example, heavy foliage on young trees which makes shaker connections difficult in daylight may be serious enough to prohibit night work, or at least reduce efficiency." However, this particular problem would be alleviated by following the recommended procedures for removal of low brush in trees.

# CONCLUSIONS

Research has demonstrated that shake-catch harvest of cling peaches for processing is feasible, practical, and economical provided there is careful management and operation of well-designed equipment in orchards prepared for machine harvest. Considerations must be given to the total system including production as well as harvesting and post-harvest handling because in each area there are factors that will influence true value of the fruit at the cannery. In this study important considerations included harvester design and operation, tree design, tree yield, and cultural practices. Tree modification is particularly important now, but will be of little concern as older orchards are replaced by those designed for machine harvest. Conclusions have been reached in each of these areas that should assist growers and canners alike in making decisions relative to harvest mechanization of cling peaches.

## Machine requirements

Good machine design minimizes loss of fruit, results in little damage to trees, and provides good machinery maneuverability. Losses resulting from dropping marketable fruit on the ground should be eliminated. This can be achieved by use of sufficient catching area, by having good closure around the tree trunk or between frame parts, and by proper maintenance of a well-designed sizer.

Decelerator strips and padding are of primary importance in minimizing fruit injury. Decelerator strips should break the fall of fruit without excessive bouncing that would result in impact to other falling fruits. Congestion of strips or catching area with broken branches or lodged fruit should be avoided. To determine if padding provides sufficient cushioning, a sample of it can be placed over a hard surface and then struck sharply with the knuckles. If padding is too soft, the knuckles will penetrate the pad and one can feel the hard surface. Good padding should comfortably pad the knuckles for the blow. To determine if the padding causes too much bouncing of fruit, a heavy ball (for example a 1-inch diameter steel ball) should be dropped on a piece of padding placed on a flat hard surface; the ball should not bounce more than about 10 per cent of the drop height. Many padding materials require a covering of a second material or a special paint to provide an abrasion-resistant surface. Such a surface frequently improves padding effectiveness.

Transfer points of fruit from the catching area to conveyors, from one conveyor to another, and from the conveying system to the bin commonly are sources of damage. In general, minimum damage will result if drop heights at transfer points are small and fruit velocities are low. Because energy is proportional to velocity squared, wide slow-speed conveyors are preferred. Bin fillers should have a drop of less than 1 foot into the bin.

Either a limb shaker or a trunk shaker

may be satisfactory. Limb shakers may be preferable for trees with short, irregular trunks, but trunk shakers are faster if the trunk will accommodate the shaker. Rules for shakers which should be followed are:

- use shakers having a clamp pad with a large area of contact
- maintain the shaker properly, particularly the clamp and clamp pads
- adjust clamp pad to avoid having it come loose while shaking, but don't use clamping that would crush the tree bark
- employ careful operators
- attach shaker approximately perpendicular to the limb or trunk.

## Training young trees

Because of their greater harvest rate, trunk shakers will probably be the predominant type used for cling peach harvesting. For trunk shaking there should be a minimum of 20 inches of clear trunk space between soil level and the start of the bulge resulting from the first primary branch. Therefore, the young tree should be headed to about 32 inches when planted in the orchard, and the first primary permitted to develop not lower than 24 inches above soil level. Because high-headed trees may have excessive trunk exposure while young, sunburn protection such as interior water-base paint or mechanical shading of the trunk may be desirable.

Three main scaffold limbs should be selected following one season's growth in the orchard. These should be spaced along and around the central trunk as recommended in pruning circulars and leaflets. Secondary scaffold limbs should start about 30 inches from the trunk; these should be at a 30° angle with the vertical axis of the tree. Branching should be permitted only in a plane tangential to the tree. This can be done by allowing only those crotches to remain which do not have forks growing away from the tree. A minimum of pruning necessary to develop the proper framework will contribute greatly to early production and early larger tree size. Small wood which develops along scaffold limbs need not be removed before the tree attains size for mechanical harvesting.

Later training should have as its major purpose control of tree shape to avoid situations where falling fruit would be likely to impact branches or other fruits after falling free for 2 feet or more. This means only one limb in a vertical plane. To improve production potential, fruiting branches may be permitted to form a continuous fruiting surface much like a vase since ladder spaces are not essential for harvest. Tree height need not be controlled as vigorously as in hand harvesting because, with proper padding and design, falling fruit can be caught without damage due to impact with the catching surface. Long hangers should not be permitted to develop because of the difficulty of fruit removal. Elimination of brush in the lower part of the tree will reduce fruit damage and improve uniformity of maturation because less mature fruit is usually found on this type of fruiting surface; removing brush will also improve visibility and increase harvester performance. Pruning cuts should be made so as to avoid producing stubs which could be a serious source of potential damage to falling fruit.

The problem of propping versus wiring for tree support has been considered in relation to mechanical harvesting. Although it is inconvenient, props can be removed ahead of the harvester in a once-through harvest system. However, if two or more passes are required for the machine to harvest individual trees at a desirable stage of maturity, props are highly undesirable. Wire bracing has a dampening effect on the transmission of energy imparted to the tree by the shaker. The problem of tree support needs further study.

These recommendations do not take into full account problems of crop control associated with pruning and thinning, as further study is needed to resolve them.

## Retraining mature trees

There are about 65,000 acres of bearing cling peach trees in California, most of which were not developed with mechanical harvesting in mind. Some of the problems these trees present to mechanical harvesting are: excessively long hangers,

stubs, rough bark, low brush, excessive numbers of primary and secondary branches, branches over one another, and trunks too short for shaker attachment. Research indicates that most of these problems can be corrected to result in acceptable levels of yield and quality. However, a short trunk with insufficient area to accommodate a trunk shaker apparently presents an unsolvable problem unless limb shakers are used or proper modifications can be made in the trunk-shaker attachment.

Tree structure varies greatly in cling peach orchards in California. San Joaquin Valley trees are generally trained upright by the modified leader system for better and stronger scaffold limb arrangement. Usually there are three or four primary branches, from which a total of six or more secondary branches arise to form a vase-shaped bearing surface. This type of structure requires only limited modification to adapt to mechanical harvesting. Training systems used in the Sacramento Valley area are more variable, ranging from the modified leader (University of California) system to the Dahlgren system. This last system permits development of excessive numbers of primary and secondary branches which may range from vertical to near horizontal; movement of mechanical harvesting equipment through an orchard so trained may be impossible without removal of some major branches. Tree structure in most Sacramento Valley orchards is somewhat intermediate between the two systems just described.

Because most damage occurs from fruit hitting low limbs as it falls through the tree, the fewer the main limbs the better chance fruit has to reach catching frames without damage. Bearing cling peach trees 8 or more years old that have been developed with more than three scaffold limbs usually have one, two, or even three limbs that serve no useful purpose. This not only increases likelihood of damage but also adds to the difficulty of mechanical harvesting. Such excess limbs often can be removed with no appreciable effect on the productive capacity of the tree, as the better-positioned limbs yield most of the fruit.

Framework limbs having too flat an angle make it practically impossible to get a good hook-up with a limb shaker, and they usually interfere with harvester operation. Therefore, these and the weaker upright limbs should be removed, along with stubs, elbows, and other parts of limbs which might be in the path of falling fruit.

Hangers 3 feet long or longer may not transmit the shaker energy normally required to remove fruit. However, it would be impossible to completely eliminate the hanger system so useful in reaching high production, and therefore hangers should be encouraged to develop but not over 2 to 3 feet long.

Low fruiting wood which develops in old trees should be removed to lessen fruit damage and increase visibility for the shaker operator. Any reduction in marketable yield that may result from eliminating this wood is likely to be of little significance, as it usually has the greenest and the smallest fruit.

## Soil preparation for mechanical harvesting

Proper soil preparation before machine harvest is essential. The first requisite is that the soil be dry enough to permit proper leveling of contours or checks so that the harvester will have sufficient traction and can be operated efficiently. Because a harvester is fairly heavy in relation to the amount of tire surface in contact with the soil, soil compaction is a potential hazard if moisture content is high. The slight potential loss of tonnage that may result from allowing the surface soil to dry sufficiently may, over the years, be more than offset by reduced soil compaction.

## Relation of nitrogen status to harvest mechanization

The influence of nitrogen level and other cultural factors on fruit quality has been studied by Claypool and Uriu (1969), and some of their findings have application to mechanical harvesting. For example, variability in fruit maturation exists between trees in all orchards, and excessively high

nitrogen levels exaggerate such differences thus increasing the variability of maturing of peaches both within a tree and between trees.

Trees in the luxury nitrogen range tend to have excessive vegetative vigor (expressed in the form of long watersprouts and a thick canopy of growth in the top) which results in shading out of lower fruiting wood. This reduces yield because it is impractical to maintain peach trees at an ever-increasing height. Peaches from trees high in N are low in skin and flesh color in relation to their firmness. Such trees are also likely to have an excessive fruit drop shortly before harvest, so that recovery of marketable fruit may be relatively low in relation to the load on the tree.

An application of 1½ pounds of actual nitrogen per tree resulted in about 3.15 to 3.20 per cent leaf nitrogen (dry-weight basis) at the time of fruit harvest. This level was highly satisfactory for maintenance of high yields and good quality. Doubling the application to 3 pounds of nitrogen per tree resulted in leaf nitrogen of about 3.40 per cent and, as a result, caused problems associated with excessive amounts of nitrogen.

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